

## **METHODS AND APPARATUS FOR TREATING DISC HERNIATION AND PREVENTING THE EXTRUSION OF INTERBODY BONE GRAFT**

### Reference to Related Applications

This application claims priority of International Patent Application Serial No. PCT/US00/14708, filed May 30, 2000, which claims priority of U.S. Patent Application Serial No. 09/322,516, filed May 28, 1999, <sup>now Patent No. 6,245,107</sup> and U.S. Provisional Patent Application Serial  
5 No. 60/148,913, filed August 13, 1999, the entire contents of each application being incorporated herein by reference.

### Field of the Invention

This invention relates generally to the prosthetic appliances and, in particular, to devices for occluding intervertebral disc defects and instrumentation associated with  
10 introducing the such devices.

### Background of the Invention

Several hundred thousand patients undergo disc operations each year. Approximately five percent of these patients will suffer recurrent disc herniation, which results from a void or defect which remains in the outer layer (annulus fibrosis) of the disc  
15 after surgery involving partial discectomy.

Reference is made to Figure 1A, which illustrates a normal disc as viewed from the feet of a patient up toward the head. The nucleus pulposus 102 is entirely surrounded by the annulus fibrosis 104 in the case of healthy anatomy. Also shown in this cross section is the

relative location of the nerves 106. Figure 1B illustrates the case of the herniated disc, wherein a portion of the nucleus pulposus has ruptured through a defect in the annulus fibrosis, resulting in a pinched nerve 110. This results in pain and further complications, in many cases.

5           Figure 1C illustrates the post-operative anatomy following partial discectomy, wherein a space 120 remains adjacent a hole or defect in the annulus fibrosis following removal of the disc material. The hole 122 acts as a pathway for additional material to protrude into the nerve, resulting in the recurrence of the herniation. Since thousands of patients each year require surgery to treat this condition, with substantial implications in  
10       terms of the cost of medical treatment and human suffering, any solution to this problem would welcomed by the medical community.

#### Summary of the Invention

          The subject invention resides in methods and apparatus for treating disc herniation, which may be defined as the escape of nucleus pulposus through a void or defect in the  
15       annulus fibrosis of a spinal disc situated between upper and lower vertebra. In addition to preventing the release of natural disc materials, the invention may also be used to retain bone graft for fusion, therapeutic and artificial disc replacement materials. The invention is particularly well suited to the minimization and prevention of recurrent disc herniation, in which case the defect is a hole or void which remains in the annulus fibrosis following disc  
20       operations involving partial discectomy.

          In broad, general terms, to correct defects of this type, the invention provides a

conformable device which assumes a first shape associated with insertion and a second shape or expanded shape to occlude the defect. The device may take different forms according to the invention, including solidifying gels or other liquids or semi-liquids, patches sized to cover the defect, or plugs adapted to fill the defect.

5           The device is preferably collapsible into some form for the purposes of insertion, thereby minimizing the size of the requisite incision while avoiding delicate surrounding nerves. Such a configuration also permits the use of instrumentation to install the device, including, for example, a hollow tube and a push rod to expel the device or liquefied material out of the sheath for use in occluding the disc defect.

10           A device according to the invention may further include one or more anchors to assist in permanently affixing the device with respect to the defect. For example, in the embodiment of a mesh screen, the anchors may assume the form of peripheral hooks configured to engage with the vertebra on either side of the disc. The invention further contemplates a distracting tool used to force the anchors into the vertebra. Such a tool would  
15           preferably feature a distal head portion conformal to the expanded shape of the device, enabling the surgeon to exert force on the overall structure, thereby setting the anchors.

#### Brief Description of the Drawings

FIGURE 1A is a cross section of a human disc exhibiting normal anatomy;

FIGURE 1B is a cross section used to illustrate a disc herniation;

20           FIGURE 1C is a drawing of a disc following a partial discectomy, showing how a space or void remains in the annulus fibrosis;

FIGURE 2 is a drawing which illustrates a preferred embodiment of the invention in the form of a flexible stent used to occlude a defect in the annulus fibrosis to minimize recurrent disc herniation;

FIGURE 3A is a drawing of an applicator used to insert the flexible mesh stent  
5 embodiment of Figure 2;

FIGURE 3B shows the applicator of Figure 3A with the stent partially expelled;

Figure 3C illustrates a fully expanded shape assumed by the device of Figure 2 following removal of the insertion tool;

FIGURE 4A illustrates the addition of optional peripheral anchors around the stent in  
10 the Figure 4 to assist in fixation;

FIGURE 4B is an end view of the device of Figure 4A including the peripheral anchors;

FIGURE 5 is a side-view drawing of the device of Figures 4A and 4B anchored into upper and lower vertebra bounding the herniated disc;

FIGURE 6A illustrates an optional distraction tool used to set the anchors of the  
15 device of Figures 4 and 5 into the vertebra;

FIGURE 6B shows how the distracting tool would be inserted into the device to effectuate distraction;

FIGURE 7A is a side-view drawing in partial cross-section illustrating the way in  
20 which notches may be made to adjoining vertebra to receive a device according to the invention;

FIGURE 7B is a drawing of a tool which may be used to form the notches depicted in

Figure 7A;

FIGURE 7C illustrates the way in which a flexible body may be retained by the notches described with respect to Figures 7A and 7B;

FIGURE 8 illustrates an alternative orientation of a flexible body having a convex  
5 surface facing outwardly with respect to the wall of the disc being repaired;

FIGURE 9A illustrates how the device according to the invention may be fixed with anchors that penetrate through the disc to be captured at the outer wall thereof;

FIGURE 9B illustrates an alternative use of anchors which remain within the body of the disc material and do not penetrate its outer wall;

10 FIGURE 9C illustrates an alternative method of fixation, wherein bone anchors are introduced into the vertebrae on either side of the disc in need of repair, as opposed to anchors deployed within or through the disc itself;

FIGURE 10A illustrates an alternative device according to the invention in the form of a resilient plug;

15 FIGURE 11A illustrates an alternative embodiment of the invention wherein a coiled wire is used to occlude a disc defect;

FIGURE 11B is a side-view representation of the coiled wire of Figure 11A;

FIGURE 11C illustrates how a wire with a coiled memory shape may be straightened and introduced using a plunger-type instrument;

20 FIGURE 12 illustrates yet a different alternative embodiment of the invention wherein a material in liquid or gel form may be introduced into a defect, after which it hardens or solidifies to prevent further rupturing;

FIGURE 13A illustrates yet a further alternative embodiment of the invention, in the form of a stent having a plurality of leaves;

FIGURE 13B illustrates the alternative of Figure 13A, wherein the leaves assume a second shape associated with defect occlusion, preferably through memory affect;

5       FIGURE 14A illustrates an aspect of the invention wherein a conformable device is suspended within a gel or other resilient material for defect occlusion;

FIGURE 14B is a side-view drawing of the embodiment of Figure 14A;

FIGURES 15A-15E are drawings which show various different alternative embodiments according to the invention wherein a patch is used inside and/or outside of a  
10    void in need of occlusion;

FIGURE 16A is a top-view, cross-sectional drawing of a version of the invention utilizing posts or darts and sutures;

FIGURE 16B is a side-view drawing of the embodiment of Figure 16A;

FIGURE 17A shows how posts or darts may be criss-crossed to form a barrier;

15       FIGURE 17B is a side-view drawing of the configuration of Figure 17A;

FIGURE 18A is a side-view drawing of a barbed post that may be used for occlusion according to the invention;

FIGURE 18B is an on-access view of the barbed post;

FIGURE 18C illustrates how a single larger barbed post may be used for defect  
20    occlusion;

FIGURE 18D illustrates how the barbed post of Figures 18A and 18B may be used in plural fashion to occlude a defect;

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FIGURE 19A is a drawing which shows how shaped pieces may be inserted to close off an opening;

FIGURE 19B continues the progression of Figure 19A, with the pieces being pulled together;

5        FIGURE 19C illustrates the pieces of Figures 19A and 19B in a snapped-together configuration;

FIGURES 20A-20E are a progression of drawings which show how a shaped body may be held into place with one or more wires to block off a defect;

10       FIGURES 21A-21C illustrate how wires may be used in conjunction with snap-on beads to occlude a defect;

FIGURE 22A illustrates the insertion of members adapted to receive a dam component;

FIGURE 22B illustrates the dam of Figure 22A locked into position;

15       FIGURE 23A illustrates one form of defect block that accommodates compression and distraction;

FIGURE 23B shows the device of Figure 23A in compression;

FIGURE 23C shows the device of Figure 23A in distraction;

FIGURE 23D illustrates the way in which the device of Figures 23A-23C, and other embodiments, may be tacked into place with respect to upper and lower vertebrae;

20       FIGURE 24A is a drawing which shows an alternative device that adjusts for compression and distraction, in the form of a resilient dam,

FIGURE 24B shows the resilient dam in compression;

FIGURE 24C shows the resilient dam in distraction;

FIGURE 25 illustrates a different configuration for the insertion of a resilient dam according to the invention;

FIGURE 26 illustrates an alternative Z-shaped dam of resilient material;

5        FIGURE 27A illustrates the use of interlocking fingers that permit compression and distraction while occluding a defect;

FIGURE 27B is a side-view drawing in cross-section of the configuration of Figure 27;

10        FIGURE 28A illustrates an alternative interlocking finger configuration, and the way in which such members are preferably installed;

FIGURE 28B shows how the first of the multiple members of Figure 28A is installed;

FIGURE 29A is a side-view drawing of a non-contained silicon blocking member prior to distraction;

15        FIGURE 29B illustrates the way in which the device of Figure 29A deforms upon distraction;

FIGURE 30A is a side-view drawing in cross-section illustrating a contained silicon structure prior to distraction;

FIGURE 30B illustrates how the contained silicon structure of Figure 30A remains essentially the same in shape upon distraction;

20        FIGURE 31A illustrates the use of threaded metal plug with particular applicability to bone graft retention;

FIGURE 31B illustrates a rigid plug with ridges enabling it to be impacted into place;



FIGURE 31C shows the use of asymmetric ridges to resist posterior migration;

FIGURE 31D shows how teeth, screw threads or ridges on certain plug embodiments would extent at least partially into the adjacent vertebra for secure purchase; and

FIGURE 32 illustrates bilateral plug positioning according to the invention.

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#### Detailed Description of the Invention

Having discussed the problems associated with post-operative partial discectomy with respect to Figures 1A-1C, reference will now be made to Figure 2, which illustrates a preferred embodiment of the invention, wherein a device in the form of a stent 202 is used to occlude a defect 204 in a human disc, as shown. In this preferred embodiment, the device is  
10 composed of a flexible material, which may be cloth, polymeric or metallic. For reasons discussed below, a titanium mesh screen is preferred with respect to this embodiment of the invention.

A flexible device is also preferred because the surgeon is presented with a very small working area. The incision through the skin is typically on the order of 1 to 1.5 inches in  
15 length, and the space at the disc level is approximately 1 centimeter on the side. As a consequence, the inventive device and the tools associated with insertion and fixation described below must be sufficiently narrow to fit within these confines.

As shown in Figures 3A-3C, a flexible screen enables the device to be collapsed into an elongated form 302, which, in turn, facilitates introduction into a sheath 304 associated  
20 with insertion. A push rod 306 may then be introduced into the other end of the sheath 304, and either the sheath pulled backwardly or the push rod pushed forwardly, or both, resulting

in the shape shown in Figure 3C, now suitable for implantation.

To further assist in fixation with respect to the surrounding physiology, anchors 402 may be provided around a peripheral edge of the device, as shown in Figure 4A. Figure 4B shows an end view of the device of Figure 4A, and Figure 5 illustrates the device with anchors generally at 500, being fixed relative to a defective disc 504 bounded by upper and lower vertebrae at 502. It will be apparent to those of skill that each of the devices disclosed herein may be made in different sizes, having varying peripheral dimensions, for example, to match differently sized defects.

Figure 6A and 6B illustrate how a distracting tool 602 may be used to force the anchors into the vertebrae. That is, having introduced the device into the approximate area, the tool 602, having a forward shape corresponding to that of the expanded mesh shape, may be introduced therein, as shown in Figure 6B. With force being applied to the tool 602, the anchors may be permanently set into the surrounding bone/ tissue.

Figure 7A illustrates an alternative approach to fixation, wherein one or more notches 700 may be made into the upper and lower vertebra, preferably through the use of an air-operated drill 704 shown in Figure 7B, having a cutting wheel 702 adapted for such a purpose. Figure 7C illustrates the way in which a flexible body 708 may be retained by the notches 700 described with respect to Figures 7A and 7B. Figure 8 illustrates an alternative orientation of a flexible body having a convex surface facing outwardly with respect to the wall of the disc being repaired.

Figure 9A illustrates a further alternative associated with fixation wherein anchors 902 which penetrate the outer wall of the disc 905 are used to hold a flexible repair device

900 in place as shown. Figure 9B shows yet a further alternative fixation modality, wherein disc anchors 906, which do not penetrate the outer wall of the disc, but, rather remain there within, are used to hold the device 904 in place.

Figure 9C illustrates yet a further alternative mode of fixation, wherein anchors 908  
5 are used to hold the device to upper and lower vertebra, as opposed to the anchors of Figures 9A and 9B, which are used with respect to the disc. Regardless of whether fixation takes place within the vertebra or within the disc, it will be noted that according to the preferred embodiment of the invention, both the device used to occlude the defect and the fixation means are sufficiently flexible that the defect remains occluded with movement of the spine,  
10 that is, with the patient leaning forwardly and backwardly which will tend to change the spacing between the upper and lower vertebra.

Figure 10 illustrates yet a different embodiment of the invention wherein, as opposed to a piece of flexible material or mesh, a resilient plug 1002 is instead utilized to occlude the disc defect. As in the case of the flexible sheath-like embodiments described above, such  
15 plugs are preferably offered in different sizes to correlate with differently sized defects.

In terms of a preferred material, a device according to the invention will therefore remain sufficiently flexible during movement while being capable of exerting continuous outward forces and withstanding repetitive compression and distraction of millions of cycles. The device would, therefore, preferably be made of a material that has these characteristics,  
20 while, additionally being radio-opaque for X-ray imaging, without producing too many unwanted artifacts in magnetic resonance imaging. A wire mesh of titanium is therefore preferable, since this has the proper X-ray/MRI characteristics while exhibiting the requisite

flexibility for the cyclic flexion and extension. With respect to the embodiment of Figure 10, a resilient, rubber-like material may be used to occlude the defect as shown in the drawing from a side-view perspective.

The invention is not limited in the sense that any conformable device may be used with a first shape permitting the device to be introduced into the defective area and a second shape wherein the device includes a defect. As shown in Figures 11A-11C, for example, a wire 1102 having a "memory effect" may be used, preferably having a final diameter which is larger than void 1104. Figure 11B shows the coil 1102 in cross-section between upper and lower vertebra. Preferably, this embodiment would use a metal wire that may be straightened, but retain the memory of its coiled shape. As such, the apparatus of Figure 11C may be used to introduce the wire in straightened form 1108 with a plunger 1110, such that as the wire exits at 1106, it returns to its memorized state of a coil (or alternative second shape operative to include the defect).

As yet a different alternative mode of introduction, a material may be injected into the disc in liquid form, then allowed to hardened into a size sufficient to occlude the annular hole. As shown in Figure 12, material 1202 may be injected into the void of the disc space using a plunger 1204 inserted into a tube 1206. Upon introduction in this manner, the liquid would then solidify, forming a resilient plug.

Various materials may be utilized for this purpose, including various polymers which are caused to solidify by various means, including thermal or optical activation, or chemical reaction as part of multi-part compounds. A preferred material with respect to this embodiment would be a hydrogel. Hydrogels may be placed into the disc in a dehydrated

state, and, once inside the disc, they imbibe water. After hydration, hydrogels have the same biomechanical properties as a natural nucleus and, in addition, as the hydrogels swell, they become too large to extrude back through the annular window. Patent Nos. 5,047,055 and 5,192,326 provide a listing of hydrogels, certain of which are applicable to this invention.

5       An elastomer may be used as an alternative to a hydrogel or other material. A number of elastomers may be suited to the invention, including a silicon elastomer, which comprises a cured dimethylsiloxane polymer and Hexsyn, having a composition of one-hexane with three to five percent methylhexaiene. A preformed elastomer may be inserted into the inclusion upon curing or, alternatively, as discussed with reference to Figure 12, may  
10   be injected into the disc space and liquid form. Chemicals may be added to accelerate curing, as discussed above, or, a hot or cold probe, or UV light may be introduced to facilitate or accelerate the curing process. Preferably, such materials would include a radio-opaque additive which would enable the physician to verify the position of the implant with an X-ray. Ideally, the radio-opaque additive would not change the mechanical properties of  
15   the gel or elastomer, and would ideally incorporate contrast throughout to enhance detail.

Now making to Figures 13 and 14, Figures 13A and 13B illustrate an alternative type of stent having leaves or other appendages that may be folded into a compact state for insertion, Figure 13A, and which expand, through memory affect, for example, to a state such as that shown in Figure 13B. A stent such as this, as well as other devices disclosed  
20   herein such as the coil form of Figure 11, may be used in conjunction with a gel or other void-filling material as described above. As shown in Figure 14A, a stent 1402 of the type shown with respect to Figure 13B, may be introduced into the void, after which the

remaining volume of the void may be filled with a material 1404 which solidifies into a resilient material. Figure 14B is a side-view drawing of the embodiment of Figure 14A. An expandable stent of this kind may be incorporated into the elastomer or other resilient material to help prevent migration of the prosthesis through the annular hole. In contrast to  
5   embodiments of the invention wherein a stent is used independently, in this particular embodiment, the stent would preferably not touch vertebra, since it would be surrounded entirely by the elastomer or other gel material.

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10   Figures 15A-15E illustrate various alternative embodiments according to the invention wherein a patch material is used inside, outside, or partially inside and outside of a defect to be blocked. Figure 15A illustrates a flat patch attached onto the outside of the disc. Figure 15B illustrates a patch attached on the outside but wherein a central portion extends inwardly into the void. Figure 15C illustrates a patch disposed within the disc to block the defect. Figure 15D illustrates how a patch may be anchored to the bone above and below the disc, and Figure 15E illustrates how the patch may be anchored to the disc itself. The patch  
15   material be a fiber, including natural materials, whether human, non-human or synthetic; an elastomer, plastic; or metal. If a fiber material is used, it may be selected so as to promote tissue in-growth. Growth of a patient's tissue into the material would assure a more permanent closure of the annular window. The patch may be attached within appropriate means, including stitches, staples, glue, screws or other special anchors.

20   In addition to the use of patches attached with sutures, staples or other materials, the annular defect may be closed with staples or other devices which attach to the annulus without the need for patch material. For example, as shown in Figure 16A, darts 1602 may

be inserted through the wall of the annulus 1604, then linked with sutures 1606, preferably in woven or criss-crossed fashion, as shown in Figure 16B. As an alternative, appropriately shaped darts 1702 may be criss-crossed or otherwise interlocked to the close the annular hole, as shown in the top-view cross-section drawing of Figure 17A or a side-view of Figure 17B.

The use of flexible stents as described elsewhere herein may take on other forms, as shown in Figures 18A-18D. The device of Figure 18A, for example, preferably includes a body 1802, preferably including a blunt anterior end to prevent penetration of the anterior annulus, and outer spikes 1806, preferably having different lengths, as best seen in the on-axis view of Figure 18B. Such a stent configuration may provide more areas of contact with the vertebral end plates, thereby decreasing the chances of stent extrusion. As shown in Figure 18C, the longer spikes 1806 are configured to bend during insertion, thereby preventing posterior extrusion. The shorter spikes, 1806', are sized so as not to engage the vertebrae, and therefore may be made thicker to prevent deflection by disc material. As an option, the shorter spikes 1806' may also be angled in the opposite direction as compared to the longer spikes 1806 to resist migration of the disc material. As yet a further option, the longer spikes may vary in length on the same stent so as to be conformal to the vertebral end plate concavity. As shown in Figure 18D, multiple spike stents of this kind may be inserted so as to interlock with one another, thereby preventing migration of the group.

As shown in Figures 19A-19C, shapes other than spiked stents may be used in interlocking fashion. In Figure 19A, a first piece 1902 is inserted having a removable handle 1904, after which pieces 1902' and 1902'' are inserted, each having their own removable

handles, as shown. In Figure 19B, the handles are pulled, so as to bring the pieces together, and in Figure 19C, the handles are removed, and the pieces are either snapped together or, through the use of suitable material, sutured into place. Figures 20A-20E illustrate a different configuration of this kind, wherein a body 2002 having anchor or wire-receiving apertures 2004 is inserted into the annular hole, as shown in Figure 20B, at which time a wire 2006 is inserted through the body 2002 as shown in Figure 20C. As shown in Figure 20D, the wire is installed sufficient to lock one portion of the body into place, and this is followed with a wire on the opposite side, thereby holding the body 2002 in a stabilized manner. It will be appreciated that although multiple wires or anchors are used in this configuration, bodies configured to receive more or fewer wires or anchors are also anticipated by this basic idea.

Figures 21A-21C illustrate a different alternative, wherein wires 2102 each having a stop 2104 are first inserted through the annular window, after which blocking beads having snap-in side configurations are journaled onto the wire across the annular hole, as shown in Figure 21B. Figure 21C illustrates how, having locked multiple beads onto the wire, the defect is affectively occluded. Figures 22A and 22B illustrate the use of a removable dam component. As shown in Figure 22A, bodies 2202, each having removable handles 2204, are first inserted on the side portions of the defect, each member 2202 including slots, grooves or apertures 2206, configured to receive a dam 2210, which may be made of a rigid or pliable material, depending upon vertebral position, the size of the defect, and other factors. Figure 22B illustrates the dam 2210 locked in position.

Certain of the following embodiments illustrate how the invention permits the use of



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a flexible device which allows movement between the vertebrae yet blocks extrusion of nucleus through an annular hole or defect. In Figure 23A, for example, a flexible element 2302 is tacked into position on the upper vertebrae, as perhaps best seen in Figure 23D, though it should be apparent that a fixation to the lower vertebrae may also be used. Figure 5 23B illustrates how, once the member 2302 is fastened in place, it may flex under compression, but return to a more elongated shape in distraction, as shown in Figure 23C. The blocking element 2302 may be made from various materials, including shape-memory materials, so long as it performs the function as described herein. Figure 24A illustrates a different configuration, which is tacked to both the upper and lower vertebrae, and Figures 10 24B and 24C show how the device performs in compression and distraction, respectively. Since devices attached to both the upper and lower vertebrae need not automatically assume a memorized shape, alternative materials may preferably be used, including biocompatible rubbers and other pliable membranes. It is important that the flexible member not be too redundant or stretched so as to compress the nerve, as shown in Figure 25. Figure 26 15 illustrates an alternative Z-shaped installation configuration.

As an alternative to inherently flexible materials which occlude a defect while accommodating compression and distraction, interleaving members may alternatively be used, as shown in Figures 27-28. Figure 27A is a view from an oblique perspective, showing how upper and lower plate 2702 and 2704 of any suitable shape, may be held together with 20 springs 2706, or other resilient material, between which there is supported interleaving tines 2708. As better seen in Figure 27B, the springs 2706 allow the upper and lower plates 2702 and 2704 to move toward and away from one another, but at all times, tines 2708 remain

interleaving, thereby serving to block a defect.

Figures 28A and 28B illustrate the way in which interleaving members or tines are preferably inserted directly to vertebrae. Since each member overlaps with the next, such tines are preferably installed from front to back (or back to front, as the case may be),  
5 utilizing a tool such as 2810, as shown in Figure 28B. The instrument 2810 forces each tack into one vertebrae at a time by distracting against the other vertebrae, thereby applying pressure as the jaws are forced apart, driving the tack into the appropriate vertebrae. The tack may be held into place on the instrument by a friction fit, and may include a barbed end so as not to pull out following insertion.

10 As a further alternative configuration, a collapsed bag may be placed into the disc space, then filled with a gas, liquid or gel once in position. The bag may be empty, or may contain a stent or expanding shape to assist with formation. In the case of a gel, silicon may be introduced so as to polymerized or solidify. As shown in Figures 29A and 29B, the use of a non-contained silicon vessel may be used, but, under distraction, may remain in contact  
15 with the vertebrae, thereby increasing the likelihood of a reaction to silicone. The invention therefore preferably utilizes a contain structure in the case of a silicon filler, as shown in Figure 30A, such that, upon distraction, the vessel remains essentially the same shape, thereby minimizing vertebral contact.

It is noted that, depending upon the configuration, that the invention may make use of  
20 a bioabsorbable materials, that is, materials which dissolve in the body after a predetermined period of time. For example, if darts such as those shown in Figures 16 and 17 are used, they may bioabsorb following sufficient time for the in-growth of recipient tissue sufficient to

occlude the defect independently. Any of the other configurations described herein which might not require certain components in time may also take advantage of bioabsorbable materials. Furthermore, although the invention has been described in relation to preventing the release of natural disc materials, the invention may also be used to retain bone graft for  
5 fusion; therapeutic materials including cultured disc cells, glycosaminoglycans, and so forth; and artificial disc replacement materials.

Disc fusions are generally performed for degenerative disc disease, spondylolysis (a stress fracture through the vertebra), spondylolisthesis (slippage of one vertebra on another), arthritis of the facet joints, spinal fractures, spinal tumors, recurrent disc herniations, and  
10 spinal instability. The procedure attempts to eliminate motion between vertebra to decrease a patient's pain and/or prevent future problems at the intervertebral level.

Devices such as spinal cages are generally used in conjunction with such procedures to maintain the separation between the vertebrae until fusion occurs. Some surgeons believe that cages are not necessary to maintain the separation, and instead use pedicle screws or  
15 hooks and rods to perform this function. Whether or not a cage is used, bone graft is generally introduced through a hole formed in the disc space to achieve an interbody fusion.

Unfortunately, bone material placed into the disc space can extrude through the hole used for insertion. Bone graft extruded through a hole in the posterior portion of the disc may cause nerve root impingement. The procedure to fuse vertebra across the disc space  
20 from a posterior approach is known as a PLIF (posterior lumbar interbody fusion). Bone can also be placed into the disc space from an anterior approach ALIF (anterior lumbar interbody

fusion). Extruded bone from an anterior approach would not lead to nerve impingement but could decrease the likelihood of a successful fusion by decreasing the volume of bone graft.

The present invention may be used to prevent the loss of the bone graft material associated with fusion techniques, whether or not a cage is used. In this particular regard, however, some of the devices disclosed herein may be more suitable than others. Generally speaking, since the goal is not to preserve disc function and motion, the stent, plug, and patch embodiments may be more appropriate. Although the plug embodiment would be a good choice when there is ample room in the spinal canal to allow insertion, the expandable stent design would be beneficial when plug insertion risks nerve injury. Conversely, since the goal is to maximize the amount of bone inserted into the disc space, the embodiments using hydrogels and elastomers might not be optimum, since such materials may occupy too much space in some circumstances.

The preferred choice of materials may also be changed since motion is not being maintained. Materials and designs with shape memory may be beneficial. As another example, the polymer plug embodiment may be changed to a metal such as titanium. A metal plug may be fabricated with threads and screwed into place, as shown in Figure 31A, or the device may feature ridges and be impacted into place (Figure 31B). As shown in Figure 31C, the ridges may also be asymmetric to resist posterior migration. In all cases, the teeth, screw threads or ridges would extend at least partially into the adjacent vertebra for secure purchase, as depicted in Figure 31D. Such plugs may also be positioned bilaterally, that is, with two per level, as shown in Figure 32.

I claim: